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Climate Change Impact on Agriculture in California

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Introduction

It was in 2019 that I listened to Greta Thunburg's speech on Climate Change at the September 2019, United Nations National Climate Action Summit. She is the youngest person ever to be named Person of the Year by TIME magazine. In her speech, she talked about how people are suffering and dying, and how entire ecosystems are collapsing. She mentioned that we were at the beginning of a mass extinction, and about the negligence of political leaders not taking adequate action, and only focusing on economic growth and profits. She expressed that for more than thirty years the science behind climate change has been crystal clear and no action has been taken. On another occasion at the World Economic Forum in Davos, Switzerland in January 2019, she stated, "Adults keep saying: "We owe it to the young people to give them hope." But I don't want your hope. I don't want you to be hopeful. I want you to panic. I want you to feel the fear I feel every day. And then I want you to act. I want you to act as you would in a crisis. I want you to act as if the house is on fire. Because it is."

I have been living in San Jose, California since 1997, and I have personally experienced a lot more warmer weather days recently, than I experienced when I first came to the area. Previously, we experienced a maximum of two weeks of warm weather during the last week of June and the first week of July. Now we are experiencing at least two months of warmer weather days. For example, the highest temperature recorded for San Jose in 1997 was 100 degrees Fahrenheit, and the highest temperature recorded thus far, for 2022 was102 degrees Fahrenheit.[1]

Watching Greta's speech, and my own personal experience got me thinking about how I could bring awareness among my students that climate change is impacting California. Since California is the largest producer of agricultural products in the United States and climate-based measurements and models project water scarcity in much of the western United States, I decided to create a unit which focuses on some of the impacts of climate change in California.

School Description and Rationale

The Franklin-McKinley School District in partnership with East Side Union High School District, Evergreen Valley College, and San Jose State University opened College Connection Academy (CCA), a Partnership School, grades 7 through 12/13 in the fall of 2008. CCA has the same autonomy and freedom to deal with curriculum, teaching and learning to meet individual students' needs. The four partners have combined and integrated their resources to make the Academy successful. CCA is located on Yerba Buena High School Campus, which allows students to take high school elective classes while in eighth grade. CCA students can earn up to one year’s worth of college credits by the time they graduate from Yerba Buena High School.

The population is made up of 200 students for the academic year 2021-2022, of which 96 are seventh-grade students, and 104 are eighth-grade students. During the past school year, the state of California provided free lunches for all students, regardless of their socioeconomic status. The student demographics are approximately, Black or African American 1%, Asian 62.9%, Filipino 3.8%**,** Hispanic or Latino 30.5%, White 1%, other races 1%, English Learner’s 9.5%**,** and Students with Disabilities 0.5%. This unit is developed for approximately 100 seventh grade general education students. All the students attending CCA are required to participate in the School District Science Fair. Learning this unit could inspire some students to generate ideas for their future Science Fair Project. Students do not have physical textbooks for science. We have science techbooks. As our curriculum is available online, students are familiar with using their computers to learn from, and research on the internet to gather information.

My school district is in San Jose, California which is a part of Santa Clara County. The Santa Clara Valley Water District (also called Valley Water) company supplies water to our area. To get the attention of drivers along Freeway 101, several billboards have been set up by Valley Water asking people to conserve water. In addition, the Valley Water District News update is asking people to conserve water as we are in a third year of acute drought.[2] Valley Water has also mandated water restrictions which allow watering lawns only two days a week, between 6 pm and 9 am in order to avoid peak hot weather times of the day, and watering that might cause a runoff.[3] Bringing awareness to my students about The Santa Clara Valley Water District (Valley Water) company’s efforts will allow them to better understand why water is a precious natural resource, and why we must water our lawns less frequently so we can conserve water. We have a lawn just outside my classroom. Students will get to observe the frequency of the lawn being water, so they know that the school is doing its part of conserving water.

This unit will focus on the impact of lower annual rainfall on agriculture in California, the impact of higher temperatures on agriculture in California, approaches for addressing water scarcity in California, approaches for irrigating crops during water scarcity, and growing less water intensive crops. Studying this unit should help my students to better understand the causes of climate change, and what measures must be taken to reduce the impacts of climate change.

Content Objectives

The city of Gilroy is approximately twenty-five miles South of San Jose, and its economy is predominantly agriculture based. Some of the main crops grown in Gilroy include garlic, tomatoes, onion, flowers, and prunes. Gilroy has gained fame as the “Garlic Capital of the World.”[4] It is best known for the annual Gilroy Garlic Festival which started in 1979 and has drawn thousands of garlic lovers from around the world. There are several stores and restaurants where people can enjoy genuine Gilroy garlic products year-round. I wish to bring awareness to my students about how agricultural practices will need to be altered in California to adapt to global climate change. Since Gilroy is located so close to my school, referring to Gilroy will allow my students to get a perspective of what crop changes Gilroy farmers will make along with the rest of the farmers in California to deal with climate change effects.

This unit is designed to bring awareness among students that climate change is happening, and how the changed climate is going to affect us in the next 50 years in California. To build background knowledge students will learn the meanings of various vocabulary words, which include annual rainfall, agriculture, chilling hours, precipitation, groundwater recharge, levees, fallowed fields, threshold temperature, hardiness zones, intense, frequent, unpredictable, replenish, variability, subsurface, climate zone, evaporation, and constrained.

Unit Content

History of Agriculture in California

Climate change is happening worldwide, and California will be no exception to its impacts. Due to climate change California will experience extreme heat waves, severe wildfires, frequent and intense droughts, inland flooding due to extreme precipitation, and coastal flooding and erosion due to rising sea levels.[5] Many of these climate change impacts will increase private, and public costs.[6] These impacts will affect humans, animals, the environment, as well as natural resources.[7]

Learning about the history of California agriculture will give students a perspective of how farming has changed between 1859 and 2007.[8] This information is from Olmstead and Rhode, 2017. Between 1890 and 1914, the California farm economy shifted from large-scale animal rearing and grain-growing crops to smaller-scale, intensive crops which include fruits, nuts, vegetables, and cotton.[9] By 1910, California emerged as one of the world’s largest producers of grapes, citrus, and various deciduous fruits.[10] Table 1 provides key statistics on the transformation of agriculture in California betweenn1859 and 2007.[11] Between 1859 and 1929, i.e., in a span of 70 years, the number of farms increased about 700 percent.[12] The average size of farms fell from roughly 475 acres in 1869 to about 220 acres in 1929, i.e., about 55 percent smaller farms.[13] These changes happened mainly because farmers switched from growing grains to fruit farms. Between 1869 and 1889, the share of California farmland receiving water through artificial means increased from less than 1 percent to 5 percent.[14] The switch from seed crops to intensive crops is credited to the development of irrigation methods and practices by California farmers. Irrigation methods included drip irrigation, sprinkler irrigation, flood irrigation, and center pivot irrigation. Growth was relatively slow in the 1890's, but expansion resumed over the 1900s and 1910s.[15] By 1929, irrigated land accounted for nearly 16 percent of the farmland.[16] Between 1859 and 1929, the real value of the state's crop output increased over 25 times.[17] Growth was especially fast during the boom of the 1860s and 1870s, mainly because of the expansion of the state's agricultural land base.[18] Successive growth in crop production was mainly due to increasing output per acre and was closely tied to a dramatic shift in the state's crop mix.[19] In terms of the crops produced, and the scale of operations in California agriculture, it was a very different place than it had been 50 years earlier.[20]

Table 1. California's Agricultural Development

	No. of Farms	Land in Farms	Improved Land	Cropland Harvested	No. of Farms Irrigated	Irrigated Land	Ag. Labor Force
	(1,000)	——(1,000 Acres)——			(1,000)	(1,000 Acres)	(1,000)
1859	19	8,730	–	–	–	–	53
1869	24	11,427	6,218	–	–	60-100	69
1879	36	16,594	10,669	3,321	–	300-350	109
1889	53	21,427	12,223	5,289	14	1,004	145
1899	73	28,829	11,959	6,434	26	1,446	151
1909	88	27,931	11,390	4,924	39	2,664	212
1919	118	29,366	11,878	5,761	67	4,219	261
1929	136	30,443	11,465	6,549	86	4,747	332
1939	133	30,524	–	6,534	84	5,070	278
1949	137	36,613	–	7,957	91	6,599	304
1959	99	36,888	–	8,022	74	7,396	284
1969	78	35,328	–	7,649	51	7,240	240
1978	73	32,727	–	8,804	56	8,505	311
1987	83	30,598	–	7,676	59	7,596	416
1997	74	27,699	–	8,543	56	8,713	260
2007	81	25,364		7,633	52	8,016	NA

Sources: Alan L. Olmstead and Paul W. Rhode, "The Evolution of California Agriculture, 1850-2000," 2003.
https://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_US_State_Level/

Table 1. California's Agricultural Development. Reprinted by permission from, "A History of California Agriculture," Giannini Foundation of Agricultural Economics, University of California, December 2017.

Figure 1 below has information from Olmstead and Rhode, 2017. It shows how cropland harvested was distributed across selected major crops over the 1879-1997 period, and displays the transformation in added detail.[21] In 1879, wheat and barley occupied over 75 percent of the state's cropland whereas the combined total for the intensive crops (fruit, nuts, vegetables, and cotton) was around 5 percent.[22] By 1929, the picture had changed dramatically.[23] Wheat and barley then accounted for about 26 percent of the cropland harvested and the intensive crop share stood around 35 percent.[24] In absolute terms, the acreage in the intensive crops expanded more than 10 times over this half-century while that for wheat and barley fell by more than 33 percent.[25]

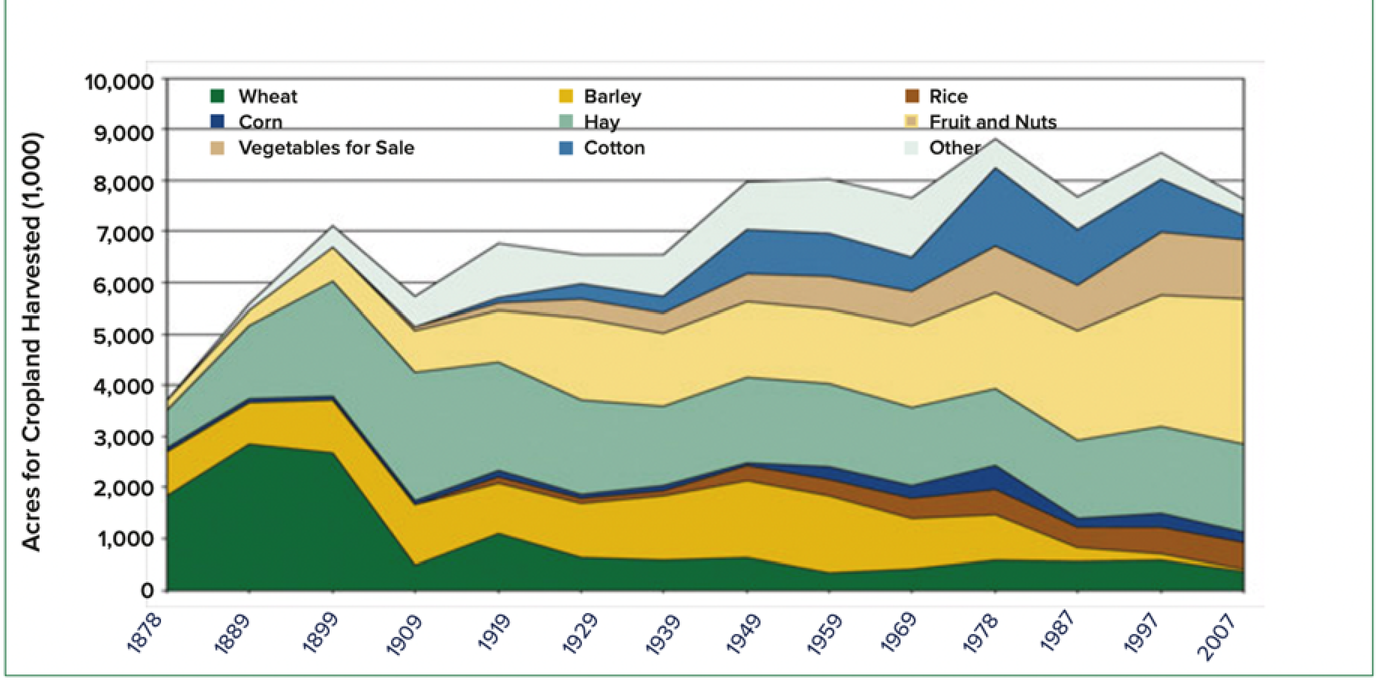

Figure 1. Distribution of California Cropland Harvested, 1879–2007

Figure 1. Distribution of California Cropland Harvested, 1879 – 2007. Reprinted by permission from, "A History of California Agriculture," Giannini Foundation of Agricultural Economics, University of California, December 2017.

Impacts of Lower Annual Rainfall on Agriculture in California

Climate change has changed the amount and timing of snowmelt that feeds our reservoirs. Annual precipitation since the beginning of the last century has increased across most of the northern and eastern United States and decreased across much of the southern and western United States.[26] Surface soil moisture over most of the United States is likely to decrease, accompanied by large declines in snowpack in the western United States, and a shift to more winter precipitation falling as rain, rather than snow.[27] This will result in a decline of food and fodder in regions experiencing increased frequency, and extended durations of lower rainfall. In California drought has led to fallowing of 540,000 acres of land at a cost of $900 million in gross crop revenue in 2015.[28] Food will become more costly. Food production depends on reliable surface and groundwater supplies which decline during periods of droughts. When domestic wells dried out in some rural areas during drought, increased groundwater pumping from deeper wells prevented some agricultural revenue losses. Drought-related agricultural changes have already led to a decline in irrigation in parts of the region.[29]

Currently, Northern California is experiencing warm and dry weather conditions. It is facing extreme swings between dry and wet conditions. It is facing challenges in managing water for farms, and the environment. 2020 and 2021 were the driest two-year periods on record.[30] The drought from 2021 raised farm costs and reduced agricultural revenue. Drought also reduced surface water to farms in 2021 by 5.5 maf (million-acre foot) which is about 41 percent less than normal.[31] When farmers have less surface water, they must pump more groundwater which adds to the costs of farming and that impacts the poorer farmers the most.[32]

History of Increased Temperatures in California

The past 115 years are now the warmest in at least the last 1700 years.[33] Global annual averaged surface air temperature has increased by about 1.8 degrees Fahrenheit (1 degree Celsius) since 1901 (Figure 2: Temperature Has Increased Across the Southwest).[34] The length of the frost-free season, from the last freeze in spring to the freeze of autumn, has increased for all regions since the early 1900s. The frequency of cold waves has decreased since the early 1900s, and the frequency of heat waves has increased since the mid-1960s.[35] Under continued climate change, higher temperatures would shift plant hardiness zones northward and upslope in the United States. Plant hardiness determines if a plant can survive in a certain place and bear fruit. These changes would affect individual crops differently depending on the crop's temperature threshold. Increasing heat stress during specific phases of the plant cycle can increase crop failures. With elevated temperatures associated with failure of warm-season vegetable crops, it could lead to reduced yields or quality in the crops. While crops grown in some areas might not be viable under hotter conditions, crops such as olives, cotton, kiwi, and oranges may replace them. In parts of California, increasing temperatures would prompt geographic shifts in crop production, potentially displacing existing growers and affecting rural communities. Wine grape quality can be particularly influenced by higher temperatures. Increased levels of ozone and carbon dioxide near the surface, combined with higher temperatures, can decrease food quality and nutritive values of fruit and vegetable crops.[36] Because many fruit and nut trees require a certain period of cold temperatures in the winter, decreased winter chill hours under continued climate change will produce fewer buds, smaller fruits, and lower yields, though the vastness may vary considerably.

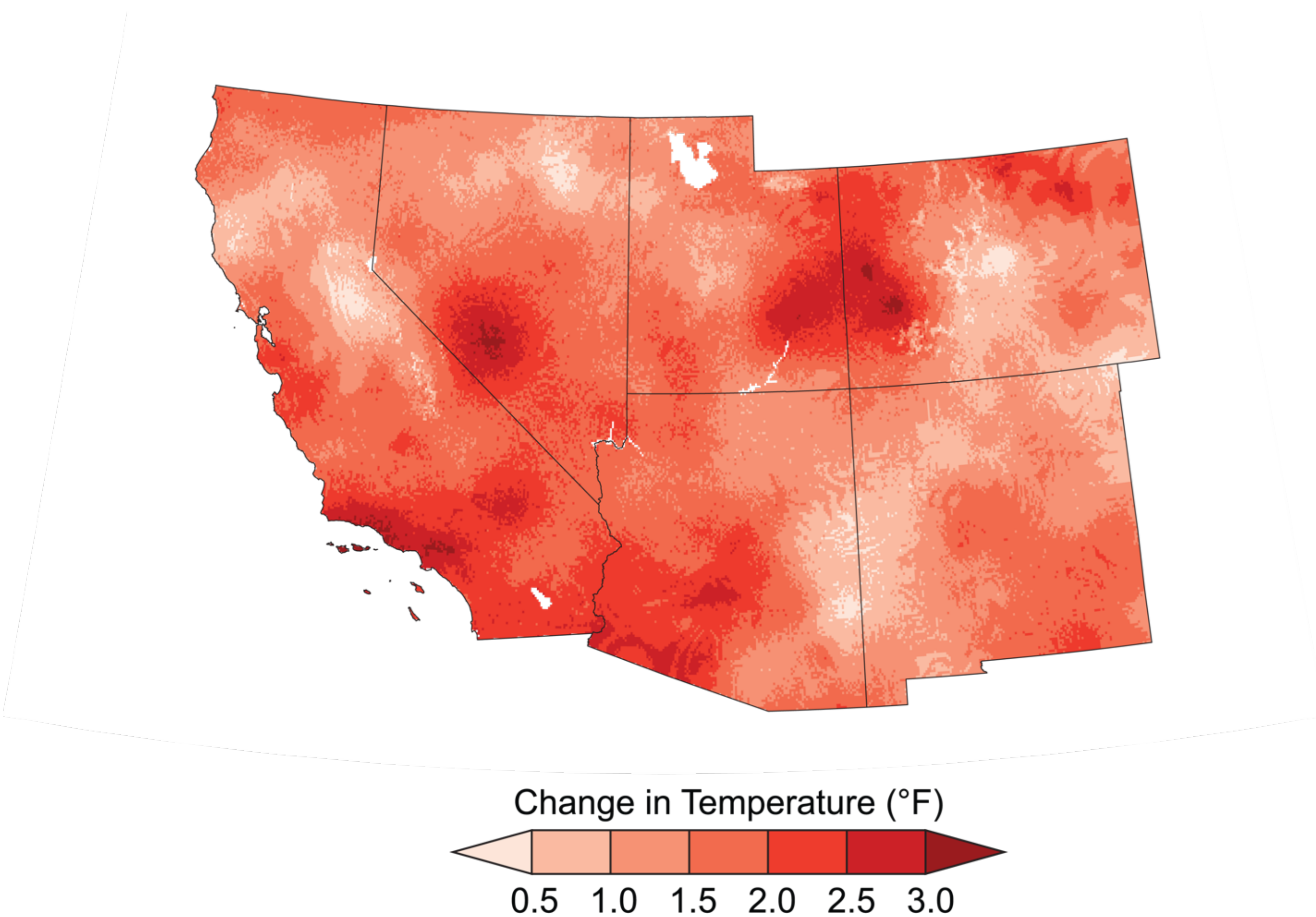

Figure 2: Temperature Has Increased Across the Southwest. Source: Fourth National Climate Assessment.

Impact of higher temperatures on agriculture in California

For the foreseeable future, with remarkable cuts in emissions, global temperature increase could be limited to 3.6 degrees Fahrenheit (2 degrees Celsius) compared to preindustrial temperatures.[37] Without significant reductions, annual average global temperatures could increase by 9 degrees Fahrenheit (5 degrees Celsius) or more by the end of this century compared to preindustrial temperatures.[38]

The number of cool nights has been decreasing since the 1950's, a pattern that threatens the possibility of growing California's lucrative wine grapes, fruit and nut tree crops.[39] To successfully set fruit, these crops depend on a certain number of "chill hours," or the number of hours at or below a certain temperature for a particular crop. Because each tree variety has a specific chill hour requirement, farmers select specific varieties of trees to maximize yields in their specific climate zone. Climate scientists predict that in a disastrous scenario, yields of almonds, walnuts, oranges, table grapes, and avocados may decline significantly in the next few decades. Shifting to new varieties with fewer chill hours is often unaffordable, given the typical lifespan of orchards and vineyards which yield crops for a few decades. Much of agricultural production depends on insect pollination. Crop failures and reduced yields can result from increased temperatures that discourage pollinator activity. Not allowing temperature to rise will benefit farmers to continue growing their crops without having to identify alternate crops.

Approaches for addressing water scarcity

Historically, considerable investments were made in water control and supply of water in California.[40] The first measure taken by Californians was to drain and protect agricultural land from flooding. To support this, farmers changed their landscape as individual farms leveled the fields and constructed thousands of miles of ditches. In addition, individual farms, and reclamation districts built several thousand miles of major levees to break the state's inland waterways. Without these investments, much of the Central Valley's land could not have been planted with intensive crops. The second measure taken was to supply the state's farms with irrigation water. This accounted for the growth of the state's irrigated acreage between 1890 and 2007 as shown in Table 1.

Constrained water resources and unpredictable precipitation patterns will be among the most challenging effects of climate change for agriculture in California. California is known for its uncertain precipitation patterns. Scientists predict even greater variability in precipitation ahead, and increased intensity and frequency of extreme weather occurrence.[41] To address water scarcity, all the available water must be captured during wet years. Groundwater recharge with rainwater during rainy seasons, when possible, will reduce the depletion of this resource. To be able to do so, we need to create the necessary infrastructure to recharge groundwater, have improved storage and reconveyance of water, and build a climate resilient water system. Increasing water recycling and building water catchment systems on farms, will improve self-sufficiency on farms. In addition, farmers can invest in soil preservation to reduce water scarcity. Building soil health by improving the organic matter content improves soil structure and allows

water to better penetrate and be retained for plant access, thereby improving the soils water retention. Organic matter can hold up to 20 times its weight in water. Organic matter also increases fertility and can reduce reliance on chemical inputs and improve plant vigor to better resist pests and diseases.[42] Farmers can practice rotational grazing. Rotational grazing is a process in which livestock are moved between fields to help promote pasture regrowth. Good grazing management increases the fields' water absorption and decreases water runoff, making pastures more drought resistant. Increased soil organic matter and better forage cover are also water-saving benefits of rotational grazing.[43] Compost used as fertilizer is known to help the growth of the plant as well as benefit the soil by adding organic matter. Mulch is a material spread on top of the soil to conserve moisture by reducing evaporation. Mulch made from organic materials that are easily available on the farm, such as straw or wood chips will break down into compost, further increasing the soil's ability to retain water.[44]

It is important to note that most agricultural groundwater is not priced, while residential water usage is. Agricultural operations pay only for the costs to extract the groundwater, not for the water itself.[45] Groundwater also isn't metered, so it's unclear how much farms are using, but it's estimated that groundwater makes up about 40% of farm use in what used to be considered an average year, meaning a year with less intense drought. In a drought year, that farm use share can jump to about 80%.[46] Having water used by farmers metered and charged, will allow farmers to know how much water they are using, and the price they need to pay for the water used. This should help bring awareness among farmers about limiting their water usage during droughts. In addition, having allocations and restrictions of groundwater to water decorative grass at businesses and institutions will also help conserve water.

Approaches for irrigating crops during water scarcity

To grow crops during water scarcity, farmers have converted to drip irrigation to improve water-use efficiency. By using a drip irrigation system, water is delivered directly to the roots of a plant, which reduces the evaporation of water that happens in other watering methods. Farmers can also plant cover crops and practice conservation tillage methods like mulch till, and strip till, to improve soil health, so their land can absorb and hold more water and better retain topsoil.[47] Additional benefits of cultivating cover crops include reduction of weeds, increase in soil fertility and organic matter, and prevention of erosion and compaction. Doing so, allows water to penetrate the soil and improves its water holding capacity more easily.[48]

Farmers should be encouraged to use technology to help reduce the use of water. Timers can be used to allow farmers to plan when their crops need to be watered. Farmers can also use a soil moisture sensor to avoid watering crops when the soil has sufficient moisture. Using information from the weather forecast will allow farmers to create an irrigation schedule which they can change according to the weather reports. All the above practices will help farmers conserve water.

Growing less water intensive crops

One of the approaches farmers can take is to switch to crops that require less water. Instead of growing tomatoes and almonds, they can switch to growing garlic and garbanzo beans. When water is short, farmers can fallow annual crops so they can water their almond and pistachio trees, where they have made long-term investments.[49] Growing crops that are appropriate to the region's climate is another way that farmers can grow more crop. Crop species that are native to arid regions are naturally drought tolerant, while other crop varieties may have been selected for their low water needs.[50] Olives, Armenian cucumbers, tepary beans, and orach are some of the more drought-tolerant crops. Dry farming is another method of growing crops where farmers depend on soil moisture to produce their crops during the dry season.[51] For dry farming special tilling practices and careful attention to microclimate are necessary. Dry farming tends to enhance flavors but produces lower yields than irrigated crops. Wine grapes, olives, potatoes, and apple trees can also be successfully dry farmed in California.[52] Organic methods of farming help retain soil moisture while keeping many of the more toxic pesticides out of the waterways. Healthy soil that is rich in organic matter and microbial life serves as a sponge that delivers moisture to plants.[53]

Teaching Strategies

Students will look up the words and their meanings on the internet. Then they will memorize the meanings of the vocabulary words. I will lead a discussion on the meanings of the vocabulary words to ensure that students build some background knowledge. We will then engage in an open discussion about the CA town of Gilroy, and what it is known for. This will allow students to make a local connection with the unit.

For the section on the History of Agriculture in California, I will engage students in an inquiry-based learning model. Students will learn how to read the information given in a table. They will learn about rows and columns in a table. Students will read, analyze, make connection, and draw a conclusion about California's Agricultural Development from the information given in Table 1. From Figure 1, they will be able to learn the location of the x-axis (always the horizontal line in the graph), and the y-axis (always the vertical line in the graph). They will be able to read the dates which are along the x-axis and learn that the dates are increasing in about 10 years increments, and the acres for cropland harvested along the y-axis, are increasing in increments of 1000 acres. Students will be able to identify how each of the crop's production has changed over time.

While teaching the section on the History of Increased Temperatures in California, students will engage in an inquiry-based learning model and identify the geographic location of the Southwest states, and the regions where temperatures have increased the most, in each state from Figure 2.

I will be engaging in direct instruction when I am teaching students the sections on the approaches for addressing water scarcity, approaches for irrigating crops during water scarcity, and growing less water intensive crops.

Students will conduct two hands on experiments to learn about how water impacts a plants growth and fruit production, and how the soil impacts the growth and production of a plant. I will create, share, and discuss the two presentations. Students will follow the directions included in the slides, while conducting the two experiments. This presentation will be a guideline for students to follow while conducting the experiments in the classroom. The presentation will include information about the amount of soil needed in each pot, guidelines to follow while potting a plant in soil, and watering instructions. The first experiment will help students learn about the importance of water for plant growth, and the second experiment is designed to help students learn the benefits of compost for plant growth and soil water retention. In addition, I will be giving direct instructions as we work on conducting the experiments in class.

Activities

Yerba Buena High School students have a kitchen garden located on campus, which my students will visit. They grow crops and have a composting center where they compost the wastage from the school cafeteria. Before we go on the trip, I will give a brief overview of what they need to pay attention to, and the observations students need to make. Students will go on a tour of the garden to learn about the crops planted, the produce they sell, the composting process, and the watering mechanisms that are used. Students will learn about the amount of time it takes for the composting process to become complete. Students will come back to class and write in their notebook about their observations from their field trip experience. They will then research about the crops that they saw in the garden and write notes about the best time of the year to grow them, the amount of time it takes for the plant to produce fruit from the time it is a seed, the frequency of the watering necessary, and the worms that need to be added to the compost bins to help degrade the food particles.

The experiments and research work on identifying crops grown in California are included in this unit to build students research, data gathering, analyzing, and interpreting skills. Experiment 1 will be conducted to learn about how a plants growth is impacted by varied amounts of water. The variable in this experiment will be the amount of water given to a plant. I will divide students into groups of four. I will assign to each group a fixed amount of water for their plant, and the frequency of the watering schedule. Students will take notes in a notebook and record data as they progress through the experiment. They will create a table for both experiment 1, and experiment 2, with the following columns: Serial number, date, quantity of water given to the plant, and plant growth observation. This experiment will be done over a period of eight weeks. At the end of experiment 1, students will learn how water impacted their plant. They should be able to conclude if their group over watered, under water, or gave sufficient water to the plant. Based on the health of their plant, they will know how plants react to water. They will then write a conclusion paragraph about what they learned from their experiment, and the status of their plant. Experiment 2 will be conducted to learn about how a plant's growth is impacted based on the type of soil and compost used. I will have three types of soil in the classroom. Type 1 soil will be soil from the school open space, type 2 soil will be potting soil, and type 3 soil will be potting soil with mulch on the top of the pot. The variable in this experiment will be the soil used. Again, I will divide students into groups of four. Each group will have a different type of soil to work with. All the students will give the same amount of water to their plant, and the frequency of the water will also be the same. Students will measure the amount of water and then water their plant. Students will take notes in a notebook and record data as they progress through the experiment. They will make entries in the table as they progress through the experiment. This experiment will also be done over a period of eight weeks. At the end of the second experiment, students will learn how soil impacted their plant's growth. They will then write a conclusion paragraph about what they learned from their experiment, and the status of the plant.

To conclude this unit, students will research and learn about the wet months, sunny months and the crop growing season in California. Then, they will identify various crops grown in California. Later, they will select one crop of their choice and go in depth about the growing season for that crop, the optimal temperatures required to grow that crop, the water requirements for that crop, pesticides if any are used, and if so, what the pesticide is, the areas the crop is grown in California, and the places the crop is exported to. They will then write a conclusion summary of their findings. Later, they will prepare a slides presentation of their research and share it with the class.

Teaching Resources

To conduct the experiments in this unit, you will need to have the following materials ready. We will be using potting soil, compost, on-campus soil, pots, radish seeds, water, and measuring cups. For conducting research, students will gather information by searching the internet using their computers.

Appendix on Implementing District Standards

This unit is designed to align with the *Next Generation Science Standards*, which have been adopted by the state of California for use in science education. By working on this unit, the following NGSS will be covered: MS-LS2-3: Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem. In this standard, the emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems, and on defining the boundaries of the system. LS1.C: Organization for Matter and Energy Flow in Organisms. Plants, algae (including phytoplankton) and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere, and water through the process of photosynthesis, which also releases oxygen. This standard teaches students how higher temperatures will impact agriculture. MS-LS2-1: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. The following standard will emphasize the cause-and-effect relationships between resources and growth of individual organisms and the number of organisms in ecosystems during periods of abundance and scarce resources.

Notes

[1] “Extreme Weather Watch,” Highest Temperatures in San Jose by Year.

[2] Valley Water Board Chair Pro Tem John L. Valera statement on adoption of water use reduction enforcement program, Valley Water.

[2] Valley Water Board Chair Pro Tem John L. Valera statement on adoption of water use reduction enforcement program, Valley Water.

[3] Valley Water Board Chair Pro Tem John L. Valera statement on adoption of water use reduction enforcement program, Valley Water.

[4] City of Gilroy

[5] Legislative Analyst’s Office, “Climate Change Impacts Across California.”

[6] Legislative Analyst’s Office, “Climate Change Impacts Across California.”

[7] Legislative Analyst's Office, "Climate Change Impacts Across California."

[8] Olmstead & Rhode, "A History of California Agriculture," Giannini Foundation of Agricultural Economics, University of California."

[9] Olmstead & Rhode, "A History of California Agriculture," Giannini Foundation of Agricultural Economics, University of California."

[10] Olmstead & Rhode, "A History of California Agriculture," Giannini Foundation of Agricultural Economics, University of California."

[11] Olmstead & Rhode, "A History of California Agriculture," Giannini Foundation of Agricultural Economics, University of California."

[12] Olmstead & Rhode, "A History of California Agriculture," Giannini Foundation of Agricultural Economics, University of California."

[13] Olmstead & Rhode, "A History of California Agriculture," Giannini Foundation of Agricultural Economics, University of California."

[14] Olmstead & Rhode, "A History of California Agriculture," Giannini Foundation of Agricultural Economics, University of California."

[15] Olmstead & Rhode, "A History of California Agriculture," Giannini Foundation of Agricultural Economics, University of California."

[16] Olmstead & Rhode, "A History of California Agriculture," Giannini Foundation of Agricultural Economics, University of California."

[17] Olmstead & Rhode, "A History of California Agriculture," Giannini Foundation of Agricultural Economics, University of California."

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[19] Olmstead & Rhode, "A History of California Agriculture," Giannini Foundation of Agricultural Economics, University of California."

[29] Olmstead & Rhode, "A History of California Agriculture," Giannini Foundation of Agricultural Economics, University of California."

[21] Olmstead & Rhode, "A History of California Agriculture," Giannini Foundation of Agricultural Economics, University of California."

[22] Olmstead & Rhode, "A History of California Agriculture," Giannini Foundation of Agricultural Economics, University of California."

[23] Olmstead & Rhode, "A History of California Agriculture," Giannini Foundation of Agricultural Economics,

University of California."

[24] Olmstead & Rhode, "A History of California Agriculture," Giannini Foundation of Agricultural Economics, University of California."

[25] Olmstead & Rhode, "A History of California Agriculture," Giannini Foundation of Agricultural Economics, University of California."

[26] Gonzalez, et al., "Chapter 2: Climate Change," Fourth National Climate Assessment.

[27] Gonzalez, et al., "Chapter 2: Climate Change," Fourth National Climate Assessment.

[28] Gonzalez, et al., "Chapter 25: Southwest," Fourth National Climate Assessment.

[29] Gonzalez, et al., "Chapter 25: Southwest," Fourth National Climate Assessment.

[30] "Farming in a state of Extremes," Public Policy Institute of California

[31] "Farming in a state of Extremes," Public Policy Institute of California.

[32] "Farming in a state of Extremes," Public Policy Institute of California.

[33] Gonzalez, et al., "Chapter 2: Our Changing Climate," Fourth National Climate Assessment.

[34] Gonzalez, et al., "Chapter 25: Southwest," Fourth National Climate Assessment.

[35] Gonzalez, et al., "Chapter 2: Our Changing Climate," Fourth National Climate Assessment.

[36] Gonzalez, et al., "Chapter 25: Southwest," Fourth National Climate Assessment.

[37] Gonzalez, et al., "Chapter 2: Our Changing Climate," Fourth National Climate Assessment.

[38] Gonzalez, et al., "Chapter 2: Our Changing Climate," Fourth National Climate Assessment.

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